Description of Analytical Tools

Name: CALifornia AGricultural Model (CALAG)

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Availability of Technical Support: A summary of CALAG documentation is available on DWR web site: (http://www.economics.water.ca.gov/documents.cfm)

Categories: Optimization of crop acreage

Main Features and Capabilities:

- *Yearly* time step
- Spatial scale at *hydrologic region*
- CALAG considers 26 crops and 56 hydrologic regions covering the entire State of California.
- CALAG projects future cropping patterns, land use, and water use by considering land and water availability and their costs, irrigation technology, market conditions, and production costs.
- The model selects those crops, acreage, water supplies, and irrigation technologies that maximize profit subject to certain constraints.
- Constraints include availability of land, water and other legal, physical, and economic limitations.
- CALAG uses Positive Mathematical Programming (PMP) technique to incorporate both marginal and average economic conditions when maximizing profit.

Applications: CALAG is an extended and improved version of Central Valley Production Model (CVPM) modified to cover the entire State. The older CVPM has already been applied in the past Water Plan Updates to forecast future crop acreage for the of the Central Valley regions. Though the current CALAG has not yet been used to forecast future crop acreage , but it has been tested with past historical data for the purpose of calibration and verification.

Calibration/Validation/Sensitivity Analysis: Calibration refers to the calculation of some model parameters in such a way that the model will predict a given set of target data. The CALAG is calibrated against two categories of information: irrigated acreage by crop and by region and applied water (or irrigation efficiency) by crop and by region. Each category represents the target parameter (e.g., acres by crop by region) and has one or more calibration parameters calculated or adjusted in order for the model to match the target. Information from 1990-1999 is used for the calibration of CALAG.

Peer Review: No formal peer review yet.

Anatomy of CALAG:

-Conceptual Basis. Conceptually, CALAG is an agricultural crop acreage model that simulates the decisions of agricultural producers (farmers) on a regional level based on principles of economic optimization. The model assumes that farmers maximize profit subject to resource, technical, and market constraints. Farmers sell and buy in competitive markets, and no one farmer can affect or control the price of any commodity. To obtain a market solution, the model's objective function maximizes the sum of producers' surplus (net income) and consumers' surplus (net value of the agricultural products to consumers) subject to the following relationships and restrictions:

(1) Linear, increasing marginal cost functions estimated using the technique of positive mathematical programming. These functions incorporate acreage response elasticities that relate changes in crop acreage to changes in expected returns and other information.
(2) Commodity demand functions that relate market price to the total quantity produced.
(3) Irrigation technology tradeoff functions that describe the tradeoff between applied water and irrigation technology.
(4) A variety of constraints involving land and water availability and other legal, physical, and economic limitations.

The model selects those crops, water supplies, and irrigation technology that maximize profit subject to these equations and constraints. Profit is revenue minus costs. From 1 above, cost per acre increases as production increases. Revenue is irrigated acreage, times crop yield per acre, times crop price. From 2 above, crop price and revenue per acre decline as production increases. Component 3 affects costs and water use through the selection of the least-cost irrigation technology. Component 4 ensures that the model incorporates real-world hydrologic, economic, technical, and institutional constraints.

-Theoretical Basis: Traditional optimization models such as linear programming rely on data based on observed average conditions (e.g., average production costs, yields, and prices), which are expressed as fixed coefficients. As a result, these models tend to select crops with highest average returns until resources (land, water, capital) are exhausted. The predicted crop mix is therefore less diverse than observed in reality. The most widespread reason for diversity of crop mix is the underlying diversity in growing conditions and market conditions. Simply put, any crop-producing region includes a broad range of production conditions. All farms and plots of land do not produce under the same, average set of conditions. Therefore, the marginal cost and revenue curves do not coincide with average cost and revenue curves. To account for crop diversity, CALAG has been formulated on the basis of marginal (incremental) conditions.

- Numerical Basis: Numerical basis of CALAG is a technique called Positive Mathematical Programming (PMP) which incorporates both marginal and average conditions. In the conventional case of diminishing economic returns, productivity declines as output increases. Therefore, the marginal cost of producing another unit of crop increases as production increases and the marginal cost exceeds the average cost. The PMP technique uses this idea to reproduce the variety of crops observed in the data. Several possible or combined reasons for crop diversity are: diverse growing conditions that cause variation in production costs or yield; crop diversity to manage and reduce risk; and constraints in marketing or processing capacity.

CALAG assumes that the diversity of crop mix is caused by factors that can be represented as increasing marginal production cost for each crop at a regional level. For example, CALAG costs per acre increase for cotton farmers as they expand production onto more acreage. The PMP approach used in CALAG uses empirical information on acreage responses and shadow prices—implicit prices of resources—based on standard linear programming techniques and a calibration period data set. The acreage response coefficients and shadow prices are used to calculate parameters of a quadratic cost function that is consistent with economic theory. The calibrated model will then predict exactly the original calibration data set, and can be used to predict impacts of specified policy changes such as changes in water supplies.

Another unique feature of CALAG is its treatment of the irrigation technologies. CALAG includes tradeoff functions, or isoquants, between water use and irrigation system cost. For purposes of CALAG irrigation tradeoff functions, water use is defined as applied water (AW) divided by evapotranspiration of applied water (ETAW). This ratio is referred to as Relative AW, and is the inverse of the most commonly used measure of field-level irrigation efficiency. Because ETAW varies regionally, using the ratio of AW to ETAW in the estimation allows the parameters of the tradeoff functions to be more site independent.

In CALAG, both applied water and irrigation system cost are decision (endogenous) variables. Profit maximizing (or cost minimizing) conditions require that the ratio of water price to irrigation technology price be equal to the ratio of the marginal products of water and irrigation technology.

Input and Output: Main categories of inputs and outputs in CALAG are as follows.

Inputs: (Water supply by source, Crop unit water use (ETAW), Ag water use efficiency, Crop production function, Crop yield, Crop demand information, Crop price, Cost of water, Cost of groundwater pumping (energy cost), groundwater pumping depths and lifts, Farm policy)

Outputs**:** (Crop acreage by region, Ag water use by region, Crop revenues, Producers profit, Consumers surplus)

Data Management: All input and output data are stored locally. Some of CALAG input data are based on field and market information (e.g. crop yield, ag water use efficiency, crop prices, cost of water). Other inputs come from the result of other models like CALSIM to provide information on amount water supply available for ag from SWP and CVP projects. CALAG is also interfaced with LCPSIM results to calculate the net value of excess urban supplies made available for ag use in wet and above normal years and transfers from ag use to urban use in dry and critical years. Information on ag water use from CALAG is also provided to CALSIM for supply allocation simulation in the latter.

Software: CALAG operates using the General Algebraic Modeling System (GAMS) software. GAMS software is available from GAMS Development Corp., 1217 Potomac Street, N.W., Washington, D.C 20007, U.S.A. This software is available for Window-based personal computers and a variety of workstations or larger computers. The CALAG code is public domain and portable across all of these platforms